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USE OF DRONES IN CADASTRAL WORKS AND PRECISION WORKS IN SILVICULTURE AND AGRICULTURE

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ABSTRACT

A new technology based on GPS and aerophotographic determinations has begun to be used on a larger scale. Currently many tractors and machines are equipped with such technology, which allows the owners and administrators of agricultural land to practice a modern agriculture called "precision agriculture". Our approach deals with two very important aspects regarding the agricultural and forest areas, namely the cadastral records and inventory and the precision works. Regarding the preparation of the topo-cadastral documentation it was very clear and relevant that the technology of aerophotography with the help of drones, is as accurate and faithful as the classic one (that is to say on the ground), only that its efficiency is much higher. Also, it has been shown very clearly that this technology has many advantages, as it allows the construction of a database, with which the forestry and agricultural specialists can easily and quickly generate a series of thematic maps that will facilitate very much their management activity. Following the researches, it was found that in the future agriculture and forestry will use drones on a larger scale, as they allow obtaining data and information in real time, as opposed to satellites, and the clarity of the images and the accuracy of the data is significantly higher, contributing greatly to modern management practice and performance, in which decisions can be made quickly and very efficiently documented.

Keywords: drones, precision agriculture, orthophotomap, GPS, thematic maps.

INTRODUCTION

The use of drones offers the possibility to collect data and carry out non-invasive measurements, from a reasonable distance, which does not affect the forest or agricultural crops studied (Bădescu et al., 2009). In forestry, this technology offers the possibility of using an alternative to the controls carried out in the classic way, by making close-ups and video feed-back in real time, as well as recording these images without the risk of accidents. Also, the main advantage is the ability to retrieve recordings with a high temporal and spectral resolution, which allows the analysis of the health status of the forest, the vegetative stage, soil and environmental conditions, at much shorter time intervals than with conventional technologies (Bergerman et al., 2016).

On the basis of this technology, analyzes can be performed regarding the interaction between environmental factors and the surface of the land (Burghilă et al, 2016). These can be represented in the form of thematic maps. Their establishment is based on theoretical principles applied in an ideal context. These thematic maps can be made in all the intermediate and final stages, necessary for a study (Gonzalez-de-Santos et al., 2017). Thus, it is possible to determine the interaction between the new elements that appeared in the field, interaction that could explain different phenomena (landslides, floods, soil type, humidity, stress, vegetative stage, pests, degree of exploitation, damage, theft, property type, species, etc.) (Rodriguez-Moreno et al., 2017; Sălăgean et al., 2011).

Drones can help farmers optimize their use of inputs (seeds, fertilizers, irrigation), respond more quickly to threats (weeds, diseases and pests), and save time for on-the-spot checks (validation of treatments or other actions). They can improve the variable application, by areas, of the fertilization / plant protection treatments for each crop, or for the real-time estimation of the yields of the crops (Călina and Călina,

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2019; Söderström et al., 2016). By mapping the area concerned, the quantities of fertilizers applied can be managed much better and also the areas where more attention is needed in terms of pollution or reduction of the amount of waste, which could have a harmful effect to the environment (Geipel et al., 2016; Sui, 2014).

The use of drones in agriculture is certainly a novelty in this field and the results obtained denote the quality of the method (Braun et al., 2018). More and more farmers declare themselves satisfied with the results obtained, which is why we expect that in the coming years we will see a real influx of beneficiaries who will try to revive the agricultural field by using technology, giving them an impetus to bring them to the first positions regarding the entrepreneurial activity (Naik et al., 2016; Şmuleac et al., 2017).

MATERIAL AND METHODS

In order to be able to make a comparison in terms of accuracy and efficiency of the use of drones in the cadastral measurements of forestry, the work team made two types of measurements for the same forested area taken in the study. The first measurement session was performed with high precision GPS-type devices and total stations, which led to high precision results, which were completely within the precision conditions imposed on such measurements.

For the determination of the coordinates of the support points, GNSS (Global Navigation Satellite Systems) methods for determining the autonomous geo-spatial position were used. The equipment used comprised 4 Leica SR530 24-channel satellite receivers with two working frequencies (L1 = 1575.42 MHz and L2 = 1227.60 MHz), preset recording interval of 5s, elevation angle 15^{o}, measurement method: static. The processing of the GNSS bases was done with specialized software (Leica Geo Office), in the ETRS 89 coordinate system, departing from the permanent CRAI (CRAIOVA) station. The detail points were measured by polar coordinate method from the support points previously determined by the GPS method, using the SOKKIA 610 total station, with data processing on the computer.

Verification of measurements and exemplification of the use of drones in cadastre and precision works in agriculture and forestry was done by applying a method previously used in the paper "Research on the use of aerial scanning for completing a GIS database" (Călina et al., 2018). This method comprises the following steps:

1. **Planning the activity and establishing the necessary resources (equipment, data, etc.)**

The following activities were carried out:

- documenting and planning the activities;
- identifying the resources needed to run the activities.

2. **Field stage - obtaining of raw data by aerophotography** implied:

- field marking of known coordinate dots which would be used for the georeferencing of the orthophotomap obtained;
- planning and conducting the flight to obtain the photograms on which the orthophotomap will be generated.

3. **Running the analysis process to identify data of interest** to the study of some similar situations / systems:

- applying the questionnaires or interview method;
- inventorying the desired information.

4. **Office stage: processing of raw data and obtaining an orthophotomap** included:

- using the purchased raw data (photograms);
- using a software product for photogramming and obtaining an orthophotomap;
- using a software product for georeferencing the orthophotomap.

5. **Designing and implementing the data model (database)** included:

- designing the data model (database);
- processing the structuring of the input data;
- processing the structuring of the output data (useful data, results);
- implementing the set data model, using a dedicated software product;
- obtaining a functional information system.

6. Development of technical documentation and instructions for use comprised:

- technical documentation for designing the geographical information system;
- manual / work procedures for using the geographical information system (case study).

7. Preparation of digital thematic maps in 2D or 3D format.

RESULTS AND DISCUSSION

The purpose of our research is twofold, the first is the cadastral one to carry out the first registration of the real estate studied in the Land Book and the second is to present comparatively the advantages and the efficiency of the use of drones in the cadastre and precision works in agriculture and forestry. The area under study was forest use category and was outside the village of Coţofenii din Dos, the 82nd field, Forest District Filiaşi; the beneficiary was a private person.

In order to identify and accurately determine the studied surface, a series of old geodesic points, of known coordinates, were used - Craiova station (CRAI) - Cârcea - Dealul Obedin - Dobromira - Dealul Viilor, with the coordinates presented in Table 1.

Using these old points determinations of new support points were made near the detail points from where detailed measurements had to be made, for the elaboration of the plan of location and delimitation on a large scale. Measurements for the determination of new support points were carried out using GNSS (Global Navigation Satellite Systems) methods for determining the autonomous geo-spatial position. The equipment used comprised 4 Leica SR530 satellite receivers, on 24 channels with two working frequencies, the measurement method - static. The processing of the GNSS bases was done with specialized software (Leica Geo Office), in the ETRS 89 coordinate system, starting from the permanent station of Craiova and Băilești. Taking into account their lengths, the short bases (less than 20 km) were processed separately from the long bases, the bases with unresolved ambiguities in the processing were not taken into account when compensating.

First we obtained - geocentric cartesian coordinates - ellipsoid WGS 84 / GRS 80 - XW, YW, ZW, for points 100, 200, 300, 400, 500, 600, 700 and ellipsoidal coordinates - ellipsoid WGS 84 / GRS 80 - (BW, LW, HW), then using the 7 parameters of a 3D Helmert transformation (dX, dY, dZ, m, rx, ry, rz), the coordinates of points 100, 200, 300, 400, 500, 600, 700, were transformed into Stereographic system 1970 and Black Sea 1975 quota system (Table 1).

Table 1. The coordinates of the old points and new points in the Stereographic system 1970

The coordinates of the old points				The coordinates of the new points		
Point	X(m)	Y(m)	Z(m)	Point no.	X(m)	Y(m)
CRAI	401599.723	316112.259	102.700	100	394591.470	320902.334
Cârcea	410600.451	310844.530	199.520	200	394128.252	321272.576
Dealul Obedin	395356.831	318651.977	172.950	300	394259.375	321981.037
Dobromira	389968.865	308925.929	179.490	400	393626.100	321428.582
Dealul Viilor	406593.520	319576.160	209.740	500	392471.213	321073.962
				600	392512.427	320905.749
				700	393132.737	321567.939

After accurately determining the support points, in order to accurately represent all the existing details on the surveyed surface, all the detail points had to be raised by the polar coordinates method, stationing one at all the support points, from where all the points of interest were targeted and which should be used in determining the surfaces and in drawing up the location and delimitation plan. In the field, the cadastral works were carried out as follows: from point 100 - GPS point, oriented on point 200 - GPS point and T95 - large basket CET 1 - Ișalnița, from GPS point 200, oriented on GPS point 100 and T95 - large basket CET 1- Ișalnița, from GPS point 600 oriented to GPS point 500 and T95 - large basket CET 1 - Ișalnița and from GPS point 500, oriented to GPS point 600 and T95 - large basket CET 1 - Işalnița, all the planimetric details were measured with the total station SOKKIA 610.

The measurements thus made were processed and, based on them, the coordinates of all points in the table with the inventory of coordinates were calculated (Table 3), after which they were compared with the coordinates obtained by using the drone. After comparing the results of the measurements obtained by the two methods, it was found that the differences on each point were very small, falling within the tolerance limits allowed. Finally, the average was made between the two measurements that were passed in Table 3, these being the definitive coordinates of the points used in the calculation of the surfaces and in the drawing up of the plan.

Regarding the use of the drone, the following steps had to be taken on the ground:

- marking the points on the ground with FENO type terminals;
- the determination of the coordinates of the points marked on the ground was performed concurrently with the classical method, because the same support points were used as in the GPS method, the target / tracked pixel size on the ground was approximately 3 cm (Călina et al., 2018);
- flight planning and execution was carried out with the open source software Mission Planner, starting from identifying and tracing the area of interest through Google Maps and calculating the approximate area that is the subject of the flight. The flight details obtained are presented in Table 2.

The collected data were processed using the Agisoft PhotoScan application, as follows:

- the first time the photograms were loaded (in raw form) in the program, creating references to them;
- validation of uploaded photograms and elimination of photograms that were not of interest in the processing process, in order to optimize the consumption of resources required for processing;

Table 2. The flight details

Flight details		Differences in flight execution (planned vs. resulted)		
Characteristics	Value	Type	Planned	Resulted / Achieved
The surface that is the subject of the work	104801 sq.m. (over 10 hectars)	Flight equipment	Drona FAE 750 Hexa - Beetle	MavicPro
Flight distance	2.06 km	Photo camera	Sony Alpha A6000L	Integrated camera
The distance between two successive shots	24 m	Photo resolution	24 MP	12 MP
Ground resolution	2.99 cm	Ground resolution	2.99 cm	2.33 cm
Number of photos	77	Numbers of photos	77	518
Number of directions / covers	5	Number of directions / covers	5	9
Ground area covered by a photo	179.4 x 119.6 m	Total flight time	6.08 minutes	About 20 minutes
Distance between directions	53.82 m	Flight mode	Automatic, previously programmed	Manual
Total flight time	6.08 minutes	Camera trigger mode	Automatic, previously programmed	Manual
Time interval between two successive shots	3.42 seconds			
Return distance	14 m			
Flight altitude	82 - 98 m			

- aligning and ordering the photos, based on the common points determined within the adjacent photograms, after which a dispersed / scattered pattern of the point cloud is generated. At this stage, the requirements of transverse and longitudinal overlap must be complied with, thus allowing us to eliminate or reposition photograms that do not meet the minimum quality requirements (Figure 1);

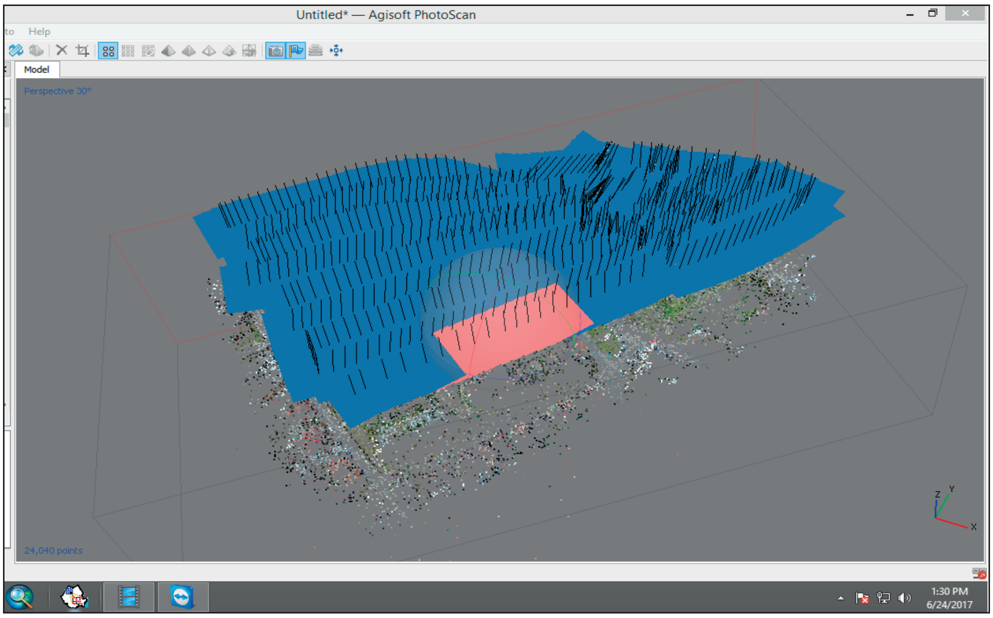

Figure 1. The result of the photograms alignment operation

- generating point cloud based on the estimated position of the camera (at the time of photograms registration) was performed to combine aerial photographs in order to obtain a dense cloud of points (which can be further processed or can be exported);

- generation of the 3D polygonal model was made on the basis of the data generated in the previous steps and based on the specified parameters;

- Surface type: height field - is the specific setting for the extended planes (especially in the case of aerophotography); Source data: dense cloud - the dense point cloud was used as a source, as it aims to obtain a high resolution orthophotoplan; Generation of the digital elevation model (DEM) - based on the processing parameters introduced; The coordinate system: Dealul Viilor 1970 / Stereo 70. It represents a land surface and can be used in various applications, such as: mapping, ortorectification, land classification, territorial planning, etc.

The next step consisted in the export of the previously obtained entities (orthophotoplan), as well as the obtained products such as: point cloud, digital elevation model (DEM), map in KMZ format.

The final step consisted in the implementation of the data model (the database), following the steps below:

1. Georeferencing map / orthophotomap based on the points marked on the ground, points for which the coordinates in the Stereo 70 system and the Black Sea altitude system were determined. The determination of the coordinates of the points of interest was performed by GPS measurements using the static method, with connection to the permanent stations CRAI (Craiova) and BAIL (Băilești). From the measurements made and processed the coordinate inventory presented in Table 1 was obtained, being used as control points for the georeferencing of orthophotoplan. In the operation of the GIS, raster images obtained using the digitization of map sheets prepared in other coordinate systems (eg L-34-144, WGS 84, scale 1:100,000) were used. Thus, for their correct georeferencing, it was necessary to transform the coordinates of the WGS 84 system into the Stereo 70 system, using the software product TransDatRO, version 4.04 (available for download at http://ancpi.ro/pages/download.php? lang = ro) (Călina et al., 2018). Following the georeferencing, a coordinate system was assigned to the map / orthophotoplan and therefore any point can be identified by coordinates in the Stereo 70 system (at the same time a system of units of measurement - the metric system - was assigned).

2. The second stage consisted of drawing / vectorizing the elements of interest (polygon type, line, point). The position and shape of the objects were represented using a system of X, Y coordinates, as in table 3, where the average coordinates of the points delimiting the studied surface were included.

There are three models of vectorization of the elements of interest (Călina et al., 2018):

- **point** type vector represented by a single pair of X, Y coordinates;

- **line** type vector represented by a ordered sequence of X, Y coordinate pairs;

- **polygon** type vector represented by a series of X, Y coordinate pairs that define the linear segments that frame the polygon (Figure 2).

Table 3. The average coordinates of the detail points resulting from the two methods

Point code	X(m)	Y(m)	Point code	X(m)	Y(m)	Point code	X(m)	Y(m)
1	320974.094	394243.954	54	321004.459	392579.577	107	320875.460	393655.228
2	320979.692	394224.027	55	320990.964	392603.393	108	320879.429	393690.951
3	320983.205	394231.843	56	320985.407	392637.924	109	320880.223	393718.338
4	321006.890	394210.710	57	320977.468	392664.915	110	320881.811	393744.535
5	321027.716	394199.796	58	320969.927	392671.663	111	320882.208	393775.098
6	321052.730	394194.318	59	320956.829	392670.869	112	320884.589	393788.196
7	321071.467	394200.744	60	320946.509	392672.457	113	320871.094	393792.165
8	321087.167	394204.879	61	320941.746	392678.807	114	320864.346	393796.928
9	321116.570	394205.830	62	320943.730	392694.287	115	320859.583	393804.867
10	321152.990	394185.803	63	320948.096	392707.782	116	320859.187	393817.171
11	321152.124	394182.655	64	320950.081	392736.757	117	320861.965	393823.125
12	321152.305	394161.743	65	320949.287	392755.810	118	320856.011	393826.697
13	321158.255	394138.729	66	320939.761	392775.258	119	320862.759	393847.734
14	321154.288	394112.541	67	320932.220	392805.821	120	320869.110	393871.549
15	321148.537	394090.917	68	320926.266	392845.116	121	320877.445	393897.349
16	321139.413	394076.037	69	320918.725	392892.350	122	320884.986	393914.019
17	321138.682	394065.803	70	320915.549	392906.242	123	320887.765	393926.721
18	321139.878	394049.715	71	320902.451	392926.484	124	320897.291	393942.597
19	321140.080	394037.800	72	320901.260	392940.773	125	320899.672	393961.253
20	321137.500	394010.190	73	320903.244	392962.207	126	320904.435	393990.625
21	321108.422	393942.329	74	320907.214	392989.595	127	320908.008	394025.157
22	321167.041	393910.418	75	320909.198	393010.631	128	320913.168	394062.070
23	321166.410	393872.440	76	320904.832	393030.081	129	320923.091	394077.153
24	321170.930	393782.080	77	320895.306	393051.117	130	320930.632	394094.221
25	321179.310	393621.700	78	320884.986	393071.360	131	320933.410	394115.654
26	321153.740	393553.320	79	320885.780	393085.649	132	320934.794	394137.454
27	321153.270	393517.050	80	320892.131	393103.114	133	320947.159	394166.823
28	321142.810	393427.690	81	320903.244	393130.501	134	320957.462	394194.352
29	321105.690	393327.120	82	320911.977	393150.744	135	321038.189	394416.840
30	321079.560	393244.370	83	320913.168	393164.239	136	321065.300	394491.516
31	321052.030	393192.970	84	320910.389	393176.940	137	321167.381	394430.436
32	321042.740	393164.640	85	320899.672	393197.183	138	321118.747	394342.307
33	321037.190	393124.370	86	320898.084	393206.709	139	321130.033	394335.790
34	321038.120	393086.460	87	320897.688	393221.396	140	321223.166	394289.669
35	321042.710	393050.630	88	320892.925	393236.081	141	321261.591	394274.399

36	321044.060	393026.690	89	320892.527	393250.768	142	321324.901	394237.817
37	321035.320	392993.250	90	320884.193	393265.453	143	321328.932	394235.487
38	321025.250	392941.950	91	320884.986	393281.330	144	321310.308	394202.183
39	321009.600	392900.970	92	320883.795	393298.001	145	321302.531	394188.276
40	321005.460	392831.960	93	320880.620	393318.244	146	321291.987	394168.862
41	320997.160	392791.360	94	320879.826	393332.930	147	321280.997	394155.665
42	321002.720	392753.700	95	320875.460	393349.997	148	321270.058	394142.861
43	321011.440	392693.520	96	320871.094	393375.400	149	321264.302	394136.089
44	321016.980	392665.800	97	320871.094	393393.658	150	321259.623	394124.095
45	321028.470	392631.780	98	320872.682	393412.710	151	321259.548	394122.288
46	321038.510	392593.760	99	320871.094	393436.923	152	321254.788	394107.589
47	321040.491	392574.424	100	320865.140	393469.470	153	321243.630	394082.640
48	321042.140	392558.320	101	320861.171	393493.682	154	321232.930	394058.750
49	321035.060	392485.089	102	320852.439	393546.472	155	321197.870	394011.490
50	321026.686	392489.874	103	320853.630	393567.509	156	321171.770	393963.600
51	321013.588	392500.194	104	320859.187	393584.576	157	321167.320	393927.230
52	321011.603	392521.230	105	320867.522	393602.835	158	320976.303	394250.539
53	321009.619	392551.396	106	320872.682	393627.047	159	321017.372	394361.360

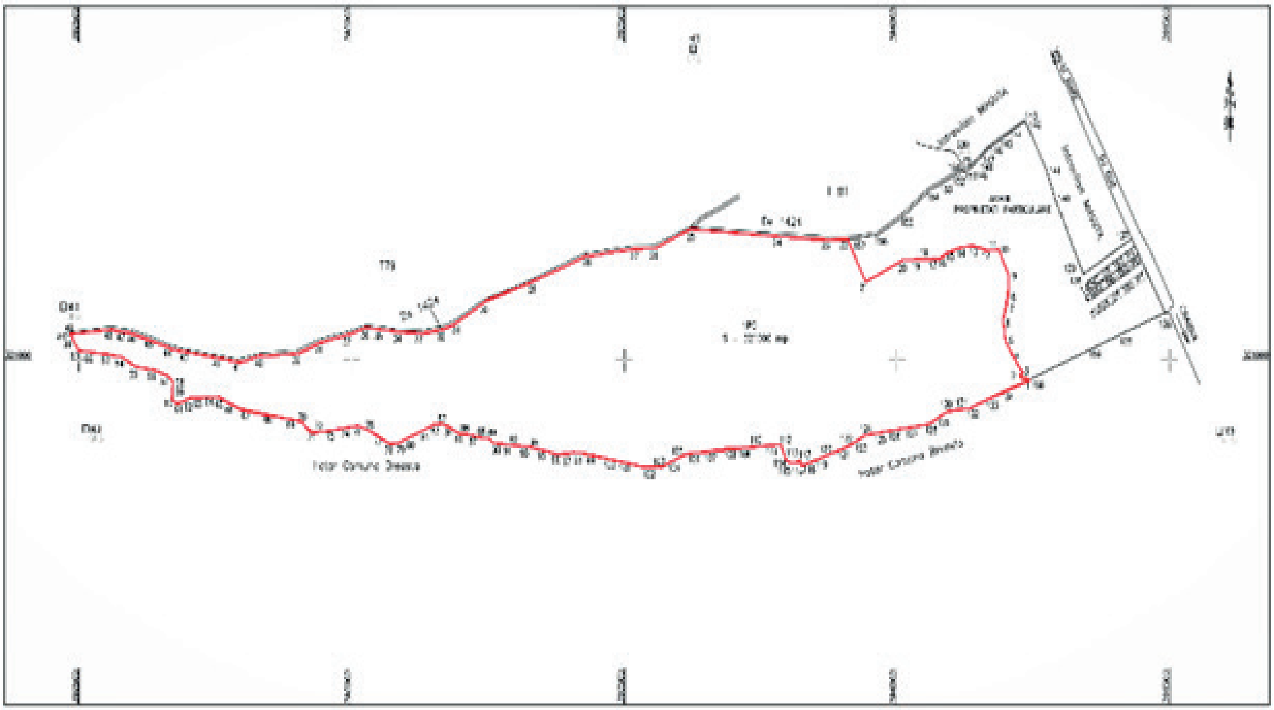

Figure 2. Location and delimitation plan at scale 1:5000

Based on the coordinates determined with high precision, as the average of the two types of measurements, the location and delimitation plan was drawn up on the 1:5000 scale (Figure 2), which was used as basic part in the realization of the topo-cadastral documentation necessary for the first inscription of the forest property, in the Land Book. Also from the coordinates of the points was calculated the area of forestry properties, which from the title of property was found to be located in the Filiași Forest District and have an area of 321000 m^2. The result of the calculation showed that the combined method used by the research team led to a precise and correct result, which is the same as that recorded in the ownership documents, ie 321000 m^2.

Based on the recorded data, 2D or 3D thematic maps were created, which were used for the graphic/visual representation of the content elements, starting from the list of attributes associated with the vector elements. For example, a 2D thematic map can be generated, which graphically presents the vectorized details according to their developed area and height regime.

In this sense, the list of properties of the layer of interest (details) can be accessed, a list in which we can specify: the mode of representation, the field / reference attribute, the number of intervals, the limits of the intervals, etc. (Figure 3). At the same time it can be observed that within the layer used the configured intervals become both descriptive element (in legend form) and elements with filtering capabilities of the presented data (Figure 3). For ease of identification / verification, labels representing the height regime of the details were set.

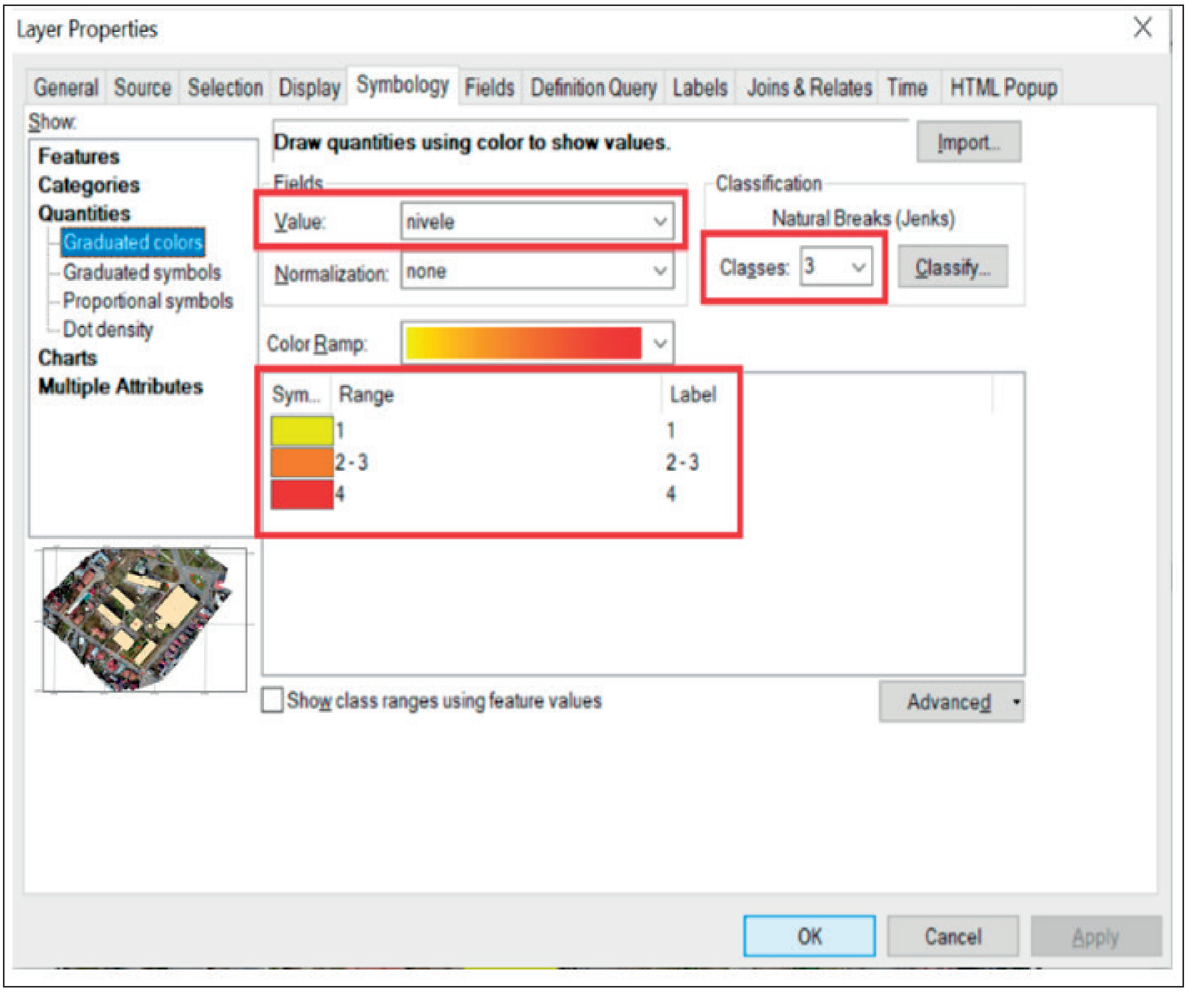

Figure 3. Creating a 2D or 3D thematic maps - select display options

On the left side of Figure 3 the options for creating a 2D thematic map are displayed - presentation according to the developed surface, and on the right side presentation according to the height regime.

The data obtained and presented as MAP LAYOUT - Arc Map offers two different ways to view a map:

1. data view - is a view mode used to explore, display or query data; is the default mode when opening any application;
2. layout view - a layout is a collection of elements of a map (map title, legend, scale, projection, etc.) positioned and organized on a virtual page before plotting / printing (Figure 4).

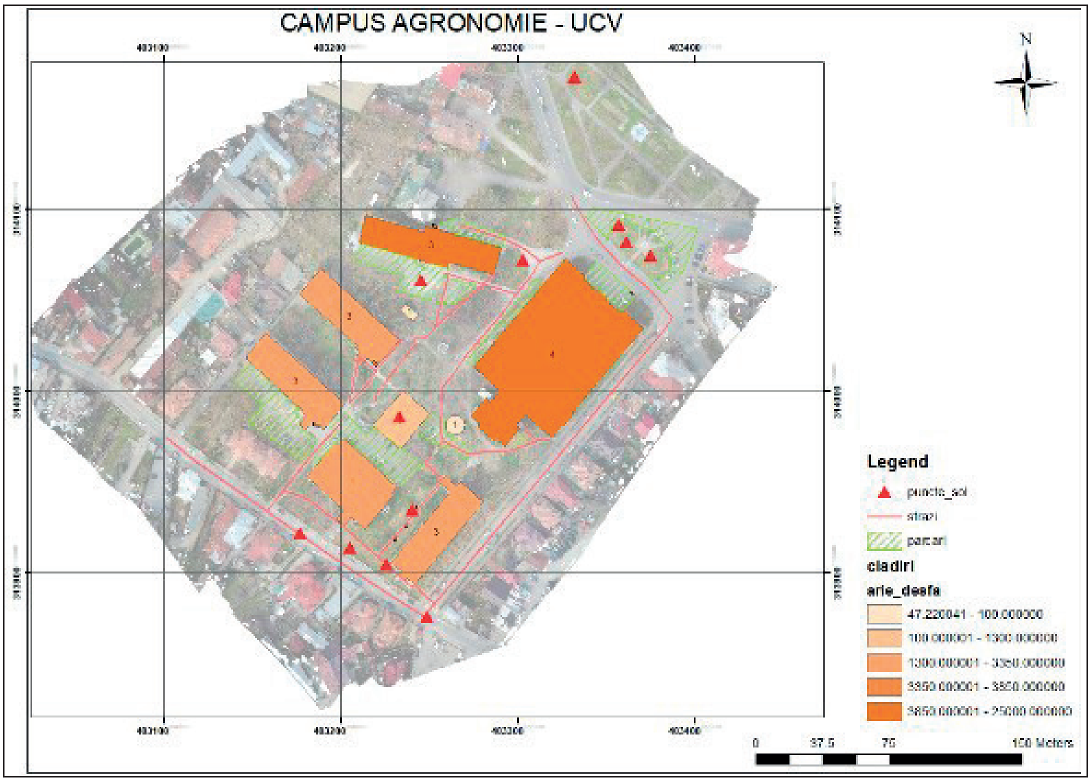

Figure 4. Layout view format - grid configuration

- Insert North direction: access the Insert -> North Arrow option, select the model and possibly configure its properties (Figure 5).

- **Insert legend**: access the Insert -> Legend option and fill in the necessary details (Figure 6).

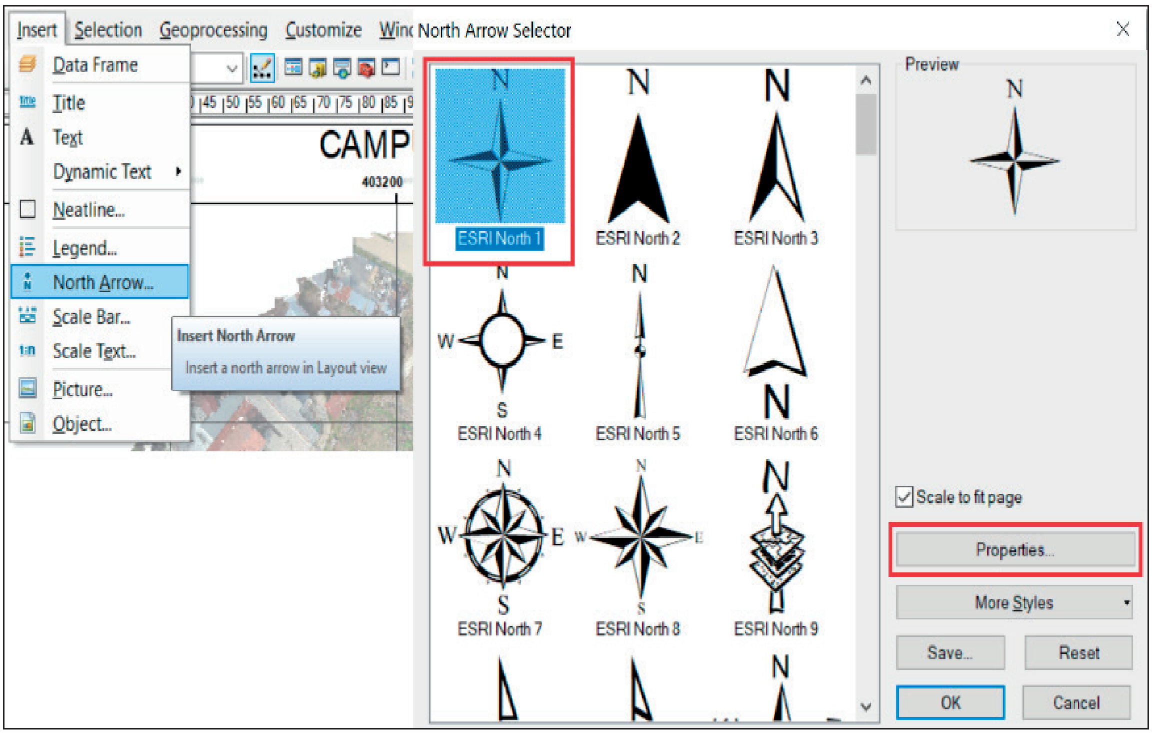

Figure 5. ”Layout view” format - North direction configuration

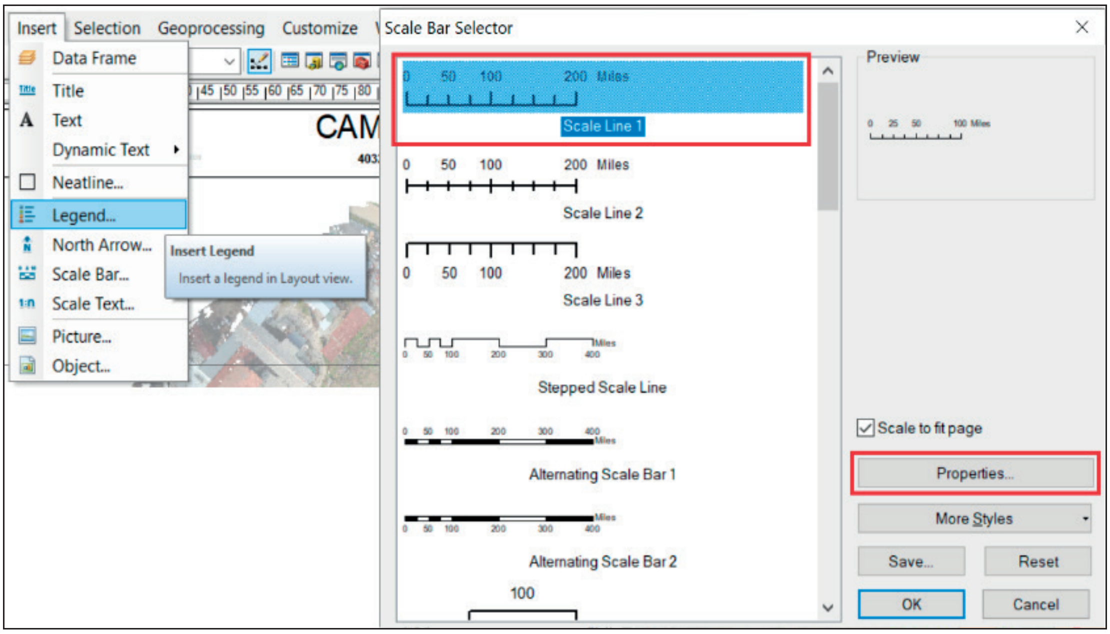

Figure 6. "Layout view" format - legend configuration and scale configuration

- **representation scale insertion**: access the Insert -> Scale Bar option and fill in the necessary details (Figure 6).

From the aspects presented in this research, drones can provide permanent field monitoring of crops, from planting to harvesting, as well as of the areas covered with forests and can achieve a higher quality and accuracy of the images in real time, because they can fly under the ceiling of the clouds, as opposed to a satellite that can provide images only once a week or once a month, when its orbit is above the agricultural or forest plot.

Based on the point cloud and these records, in the forestry and agriculture works a number of products of special importance for landowners can be obtained, such as: the database created can be exploited for precision agricultural works, because at present almost all tractors and agricultural machines machines are equipped with GPS technology; diagnosing the state of health or stress of different types of crops and surfaces with woody vegetation; thematic maps with the degree of soil supply in the main nutrients (N, P, K, as well as a series of microelements); thematic maps with the precise determination of the areas affected by the different phyto-pathogenic agents, in order to implement the most effective preventive methods; thematic maps with the degree of coverage of the vegetation surfaces and their division into categories; thematic maps with the influence of different factors on the protected areas (roads, railways, localities, waterways, etc.); thematic maps on which the census of certain species of plants and trees is made; thematic maps on which vegetative indices are represented (leaf volume, anomaly detection, treatment efficiency, infestations, influence of meteorological factors, etc.); thematic maps with the water requirement of the plants and the damage caused by the prolonged drought; thematic maps with small production and agrotourism activities, etc. (Ciolac et al., 2019).

At the same time, using them we can obtain important advantages for the topographic works as for example: the creation of the orthophotoplan of the studied area, of the 3D model of the terrain, of a situation plan with the representation of the slopes and of the microrelief of the land (accumulations of water respectively water deficit), of the thematic plans / maps in the case of the use of thermal camera (Călina and Călina, 2019).

CONCLUSIONS

The application of drone technology in combination with the more classic measurements, such as GPS and total stations (on ground) led to obtaining particularly significant results in terms of accuracy and efficiency of the measurements made. The ease and speed with which the measurements and recordings of high precision data can be made, by using low altitude aerial photo scanning with the help of drones should also be noted. All determinations made with drones can be made in real time, i.e. when farmers and foresters have the greatest need for the data they need to collect, in relation to the general state of the crops and forest areas.

A very significant aspect to be emphasized is the fact that based on the measurements made and the new databases created by the specialists in agriculture and forestry, they can generate a series of thematic maps with a very wide applicability, which will contribute substantially to the way and the speed of taking decisions, regarding the evolution and health status of the crops as well as the choice of the optimal moment regarding the necessity and the obligation of the intervention with different inputs, in order to obtain significant production increases, in all cultures.

The newly created databases help a great deal in the application of new technologies in agriculture, namely the realization of "precision agriculture", which implies the application of agricultural works with an "almost surgical precision", which allows the crop management and treatments to be carried out without any mistakes and the inventory in real time of the works carried out and their quality. Also, this database can contribute substantially to the improvement of the management of agricultural and forestry enterprises, because all tractors and machines can be tracked in real time, which allows the manager the possibility to remove almost totally dead times and waste of fuels and inputs, as well as the possibility of stealing crops, goods or wood in the case of forests.

As regards the cadastral works, this technology can have many advantages, such as the access to inaccessible, difficult or dangerous areas for the cadastral specialists, their safety by performing remote measurements, performing the liftings by a non-invasive method, high efficiency by performing them in a short time and with a high resolution of the order of the pixels, the possibility of equipping them with different types of cameras: visible spectrum, infrared, thermal, HD video, etc., aspect that offers the ability of the users to obtain data and fast information, in almost any kind of conditions.

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